cumference of the revolving plate. At the end of three minutes and forty-nine seconds, when the plate stopped, the east-west pen continued to register slow vibrations of over half a centimeter, (one-quarter of an inch) double amplitude.

The record is complicated by the natural swing of the pendulums, and friction. To interpret the curves correctly, these must be taken into account. The horizontal pendulums swing with a free period of about seven seconds and come to rest from a maximum swing in a little over one complete vibration, if undisturbed. The vertical pendulum has a period of about four seconds, and will make about four complete swings. Small vibrations of the "earth particle," synchronous with the natural period of a pendulum, if continued, will soon set it swinging with large amplitude. In a less degree, oscillations of a different period will excite forced vibrations, with the resultant sort of compounding well illustrated by the last minute of the east-west record.

North, west and upward displacements are indicated by inward motion of the respective pens. To determine the real displacement in either component, the displacement shown in the cut, measured in the direction of a radius of the plate, after eliminating the instrumental effect, must be multiplied by the proper factor, following: N.S. 1.32, E.W. 1.44, Vert. 3.04. The actual direction and magnitude of the displacement at any moment, is obtained from the reduced component displacements, by simple compounding by parallelogram constructions. JAMES D. MADDRILL.

ON THE EARTHQUAKE OF APRIL 18, 1906.

It is not necessary to say that the earthquake of April 18th was very severe on Mount Hamilton, but it is a matter for congratulation that the observatory suffered no serious injury. Director CAMPBELL was in Washington, D. C., at the time, and Astronomer TUCKER was in charge. It was found that the telephone connection with San José was destroyed, and, as fires were observed to break out at once in San Jose and San Francisco, the seriousness of the situation was soon realized. Professor TUCKER dispatched a bicycle messenger to San Jose, bearing the message that "The buildings and instruments of the Lick Observatory were not injured by the earthquake." All was confusion in San Jose and there was no telegraph or telephone communication with the outside world. The messenger therefore rode on to Berkeley, 75 miles

from Mount Hamilton, and delivered a copy of the message to President WHEELER of the University, late in the afternoon of the 18th. As it was not possible to send private dispatches, the message was delivered to the Associated Press, with the request that it be sent over the wires as soon as possible. This was done on the 19th, and the message was correctly published in many eastern papers of the 20th. A Chicago paper containing it overtook me in Iowa on the forenoon of the 20th, as I was speeding westward, and the relief afforded will not soon be forgotten. It was hoped that this information would reach all inquiring friends of the observatory, both in this country and abroad, but there soon appeared to be considerable doubt of this. On this account the message was at our request repeated a week later by the Associated Press.

The details of the earthquake are given for Mount Hamilton in Mr. MADDRILL'S note. The maximum double amplitudes of the motion here could scarcely be less than, and perhaps exceeded three inches. Fortunately, the period of vibration was long, and the buildings and instruments apparently had time to follow the earth motions. The tops of three large and one small brick chimneys were cracked, but not broken off. A great many old cracks in plastering were reopened, and many new cracks were formed. These apparently comprise the damage on the mountain. The brick and cement reservoirs and the water systems were not affected. Professor TUCKER'S observations with the meridian circle established that the instrument's position had not shafted appreciably. At my request, Dr. AITKEN and Dr. MOORE determined the position of the polar axis of the 36-inch refractor. They found no significant change.

This immunity, so to speak, is somewhat surprising, in view of the fact that the damage in San Jose, only thirteen miles directly west of us, was severe, and that in regions thirty to fifty miles east of us a large proportion of chimney tops were thrown down. Altitude alone can scarcely be a protective factor. The breaks in the rock strata between this observatory and the origin of disturbance—there are two narrow valleys between us and San Jose—are probably potent factors in reducing intensities. It is a familiar fact that earth waves of great destructiveness on one side of a mountain range often reappear destructively on the other side, as in the present case, with only minor destruction in the mountains themselves; but the explanation of these phenomena is usually not apparent. There can be no doubt,

however, that the rigid rock foundations of our buildings and instruments were exceedingly important elements in their stability, under the severe strains suddenly thrown upon them.

The indirect effects of the catastrophe upon the finances of the Lick Observatory and other State institutions cannot now be determined. Even though a way be found to maintain present incomes, there can be no doubt that further development, from State funds, will be seriously limited for many years to come. This is in no sense a statement of discouragement, as it is hoped that, as in the past, other sources of income may present themselves as needs arise.

The earthquake was destructive on a narrow belt extending along the coast from near Eureka in the north to Salinas in the south, a distance of about 300 miles. More than half the people of the State, and more than half the property are located in the affected district. The direct earthquake destruction was a minor matter, perhaps not exceeding $35,000,000, but the fire in San Francisco destroyed property valued at between $500,000,000 and $800,000,000, or roughly, one-fourth or one-fifth the assessable property of the State. One-third to one-fourth of this loss will probably be borne by insurance companies in other states and countries. Those State institutions which depend upon pro rata taxation for their support have lost a corresponding proportion of their income. The University of California loses $50,000 or $60,000 in this manner. It lost, besides, uninsured business property in San Francisco, whose annual rental was $60,000. The State of California will, no doubt, repair these losses, as far as it is financially able; and there are no people in the world more ready to support higher education in all its forms and phases, to the extent of their ability, than are the people who compose the commonwealth of California. They are both unusually practical and unusually interested in the ideal.

Four-fifths of the normal income of the Lick Observatory consist of State funds, assigned to it by the Regents of the University. These financial statements are made in deference to many inquiries from distant friends.

On the day following the earthquake, His Excellency, Governor GEO. C. PARDEE, appointed a State Commission to investigate the scientific aspects of the phenomenon. The Commission consists of Professor A. C. LAWSON, University of California, chairman; Professor J. C. BRANNER, Stanford University; Professor GEORGE DAVIDSON, University of Cal-

ifornia; Professor HARRY FIELDING REID, Johns Hopkins University; Dr. C. K. GILBERT, U. S. Geological Survey, Washington; Professor A. O. LEUSCHNER, University of California, Secretary; and Director W. W. CAMPBELL, Lick Observatory, University of California.

The Carnegie Institution of Washington has generously undertaken to defray the expenses of the investigation.

The work of the Commission is well organized and many facts of extreme interest have been established. The principal fact is that the earthquake was due to very extensive motion of the strata along a well-known geological fault that runs near the coast line. The motion was principally of the horizontal-shearing type, with few apparent evidences of any vertical component. The geological members of the commission have traced the *surface fissure* along the fault line practically continuously from the mouth of Alder Creek, just north of Point Arena, south to Fort Ross, where the fissure enters the ocean; thence from its reappearance in Tomales Bay, south to Bolinas Bay, where it again enters the ocean. It undoubtedly passes under the ocean about two miles out from the Golden Gate, as it re-enters the land some six or eight miles south of the Golden Gate and follows the old fault line continuously south-south-east to a point a short distance southeast of Salinas. On the east side of the fissure the strata have moved south, and on the west side they have moved north, relatively. The relative motion appears to be a maximum in the Tomales-Bolinas region, about 20-25 miles northwest of San Francisco. A public road crossing the fault line at right angles has now an offset of seventeen feet at the fault line. A large tree standing exactly on the east edge of the fissure is now twenty-four feet south from the small roots which it left in the west bank of the fissure. A path crossing the fissure is offset eighteen feet; three trees formerly stood in a row about seven feet east of a small house. The fissure passes between them and the house and they are now eighteen feet southerly from the house. A barn is situated exactly over the fissure, some four-fifths of it being on the west side. Although badly wrecked, the superstructure remains with its foundation west of the fissure, but that part of the foundation lying east of the fissure has moved southward under the barn, through eighteen feet. A fence crossing the fault line is offset eighteen feet at the fissure. About twenty miles westward from Mount Hamilton, on the fault line, the offsets are about eight and one-half feet, as a maximum. All the offsets referred to are in the thick loamy

soil, and it is possible that, on account of lag in the soft soil, the shear in the underlying rock stratum is larger.

Many interesting questions are raised as to disturbances in boundary lines between farms, in latitudes, azimuths, etc.

The same geological fault extends southeasterly throughout the State to the vicinity of the Colorado River, and perhaps further.

W. W. CAMPBELL.

THE CALIFORNIA EARTHQUAKE AT UKIAH.

The great earthquake of April 18th was very severe at Ukiah, 160 kilometers (96 miles) northwest of San Francisco. Many chimneys were thrown down and three brick buildings were partially wrecked. There were a series of shocks and reliable estimates of their duration vary from twenty seconds to one minute. The general direction of the waves seemed to be from the south to the north, although on the eastern side of the valley the damage to the buildings of the State Insane Asylum seemed to be almost entirely from the east and west movement.

At the Latitude Station no damage whatever, was done. The observatory clock, which faces south, was not stopped, but it lost six seconds during the disturbance, which is equivalent to being stopped for that length of time and then set to going again. The pier upon which the zenith telescope rests, is apparently not damaged, but the telescope was thrown considerably out of adjustment. It was out about fifteen seconds of arc in azimuth and the vertical axis was out in both directions, but not much more than sometimes results from extreme changes in temperature.

The first series of shocks was followed by three lighter ones, and the observed data for each are as follows:

Pacific Standard Time of Beginning	Duration	Direction	Intensity Rossi-Forel Scale
1906, April, 18d 5h 12m 17s a. m.	About 40s.	S. W. to N. E.	VIII. to IX.
18d 10h 4m 39s a. m.	About 10s.	S. W. to N. E.	IV.
18d 11h 39m 00s a. m.	About 30s.	S. W. to N. E.	III.
20d 12h 30m 53s a. m.			I.

The first time given is uncertain to the extent of five seconds, possibly more, either way. The other times are correct within two, or at the most, three seconds.

I was in the observatory at the time of the second series of shocks, at 10h 4m, and perceived the effect of the movement in the striding level, (east and west) of the zenith telescope. The bubble oscillated over about two divisions of the